A Proposal for Fast Detection Movement in Mobile IPv6

Javier Carmona-Murillo[1], José-Luis González-Sánchez[2], David Cortés-Polo[3], Francisco-Javier Rodríguez-Pérez[4]

Department of Computing and Telematics System Engineering, University of Extremadura
Av. Universidad s/n 10003. Cáceres - SPAIN

[*1]jcarmur@unex.es; [2]jlgs@unex.es; [3]dcorpol@unex.es; [4]fjrodri@unex.es

Abstract

One of the main goals in the design of Next Generation Wireless Networks is the possibility to keep the connectivity of a user while it moves among heterogeneous networks. The IETF (Internet Engineering task Force) has designed some protocols in order to solve this problem. One of them, Mobile IP, has been chosen as the core mobility management mechanism for wireless LANs and 4G cellular networks. One of the most critical stages of the mobility process is the handover management. The high delay of this phase is a limitation to seamless mobility. In this work, a detailed analysis about handover process has been presented. Moreover, movement detection is a very costly stage in handover mechanism so a new fast movement detection algorithm to improve this detection has been developed, called FDML3 (Fast Detection Movement Layer 3). Through the simulation of the algohoritm, the benefits of the proposed algohoritm have been shown in terms of handover latency compared to Mobile IPv6 mobility management protocol.

Keywords

Mobile IPv6; Handover; Movement Detection; OMNeT++

Introduction

In recent years, mobile communications have been in a continuous evolution. This situation has changed the traditional way of Internet access. Convergence between TCP/IP and wireless networks is a challenge to achieve seamless mobility in heterogeneous networks.

Until now, mobility has been limited to the same access technology and a single administrative domain. Next step in Internet access evolution is to offer mobility in heterogeneous networks and among different AS (Autonomous Systems) maintaining uninterrupted sessions while the physical interface is changing (*C. Masaya, et al., 2007*). To achieve this goal, mobility management must be implemented in a common level to all technologies. IP is the best candidate to offer this mobility (*F. M. Abduljalil, et al., 2007*). However, IP protocol does not allow a node to move among different networks without a connection disruption. IETF has solved this problem with the development of a new protocol: Mobile IPv6 (hereafter MIPv6) (*C. Perkins, et al., 2011*). One of the most critical phases in the protocol is the handover or handoff produced when a mobile node moves to a new IPv6 subnet while connection is still alive. This movement must be seamless to the user, so it is important to reduce the overall time of handover delay composed of movement detection delay; new IP configuration; and address registration in its home network (*R. S. Koodli, et al., 2007*).

Some of the goals of this work are the handover analysis and its improvement with the reduction of the most costly stage in this process: the movement detection. A new fast detection movement algorithm at layer 3 called FDML3 has been developed to improve the overall delay of the handover. This article is organized as follows: In Section 2 both mobility problem in IP networks and MIPv6 protocol are presented; section 3 is focused on detailed handover analysis; the proposed FMDL3 algorithm is explained in Section 4; next, simulation results are shown in Section 5; finally, conclusions and future work are presented in section 6.

Mobility Support in IP Networks

In general, a host in the Internet exchanges data with other nodes thanks to TCP/IP architecture. These protocols were designed for fixed hosts which are identified by an IP address, composed of a NetID and a HostID. The fact that all nodes in the same network share a common prefix is the main reason why IP routing scales so well.

Fig. 1 shows the limitation of traditional IP routing when a mobile node moves to a different network. It is

necessary to develop mechanisms to offer mobility in the Internet. The first possibility changes the IP address in each movement, but this is not a good solution due to scalability and security problems.

Furthermore, TCP identification is generated using IP address, thus an IP change makes that all TCP connections will be closed. Other mechanisms have been proposed from different levels of TCP/IP stack. A comparison of the proposed solutions for providing mobility support on the Internet is presented in (*D. Le, et al., 2006*). Convergence towards "All-IP" architectures in NGWN (Next Generation Wireless Networks) has made IETF develop a protocol called Mobile IP which is the main solution to offer seamless mobility in the Internet (*F. M. Abduljalil, et al.,*). Mobile IP has been developed in two versions: Mobile IPv4 and Mobile IPv6. This work is based on MIPv6 version, because when IPv6 is designed, mobility is taken into account, so this release solves some drawbacks of the previous version (*J. Mangues-Bafalluy, et al., 2004*).

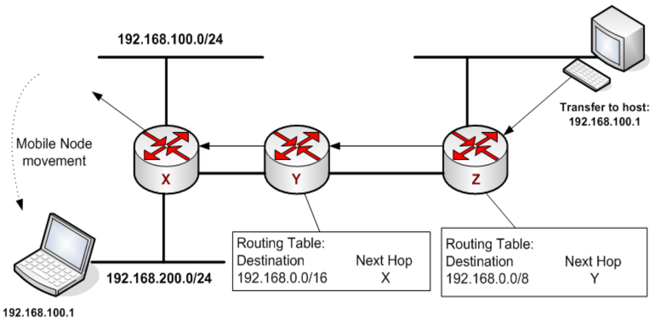

FIG. 1 IP ROUTING DOES NOT SUPPORT MOBILITY

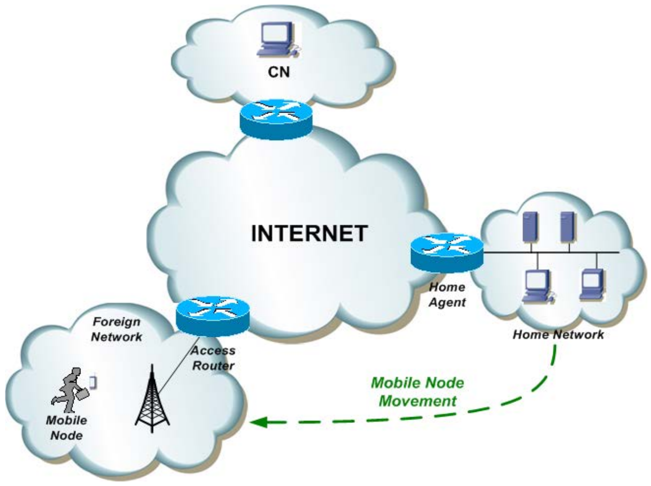

FIG. 2 MOBILE IPv6 ENTITIES

MIPv6 introduces new terms and functional entities as Fig. 2 shows. This protocol allows mobile nodes to change its point of attachment without losing its ability to communicate. This goal is reached by keeping a permanent IP address in the Mobile Node (MN) called Home Address (HoA), which belongs to its Home Network. The MN also obtains another temporary IP address (CoA, Care-of Address) that is valid and routable at the Mobile Node's current point of attachment in a Foreign Network. The Home Agent (HA) is an IPv6 router in its home network that intercepts packets destined to the mobile node's HoA and sends them to the mobile node's current location while it is away from home. Another entity in MIPv6 operation is the CN (Correspondent Node), a peer node with which the mobile node communicates.

Finally, an important data structure is the Binding Cache, which is maintained by home agents and correspondent nodes and contains a matching between the HoA and the CoA.

MIPv6 operation follows the three phases shown in Fig. 3. Some researchers consider handover as a fourth stage in MIPv6 operation due to its importance. Handover process occurs when the mobile node makes a movement. In that case, it changes its point of attachment to the Internet. During this process, communication may be interrupted and delay increased.

Depending on the type of handover, the process is more complex, as it may entail changes in the access point, the access router, the access gateway, the access technology and/or the administrative domain. Handover is one of the costlier processes in Mobile IPv6.

Some approaches to reduce movement detection latency are based on layer 2 information, so faster than layer 3 ones. These solutions have an important disadvantage because they restrict the movement among heterogeneous networks due to layer 2 access technology dependence.

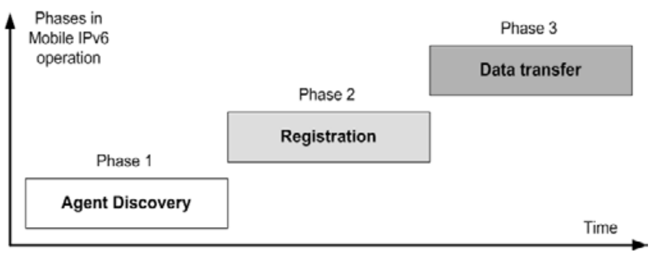

FIG.3 MIPv6 OPERATION PHASES

Performance Evaluation of MIPv6 Handover

From the point of view of the network, mobility management is tackled from two different perspectives. In this sense, we distinguish the movements carried out in an administrative domain confined to a geographical area, which is called local mobility or micromobility and the global mobility or macromobility.

This global mobility manages the movements in wide areas, where there are generally different access networks which even can belong to different administrative domains. MIPv6 was developed to solve macromobility movements.

Mobility management protocols are designed to solve overhead, packet loss and path recovery latency during handover process. Handover management is one of the key issues in order to support global roaming of mobile nodes among various wireless systems in an efficient way. MIPv6 handover process consists of the stages shown in Fig. 4.

In general, handover latency is defined as the interval starting from the moment when the mobile node leaves the old access medium until it resumes communication with the correspondent node at the new access medium. Fig. 5 shows this process, composed of three components that cover the stages aforementioned.

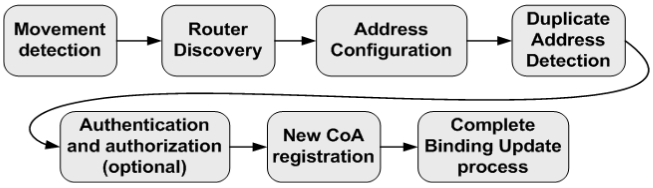

FIG. 4 PHASES IN HANDOVER PROCESS

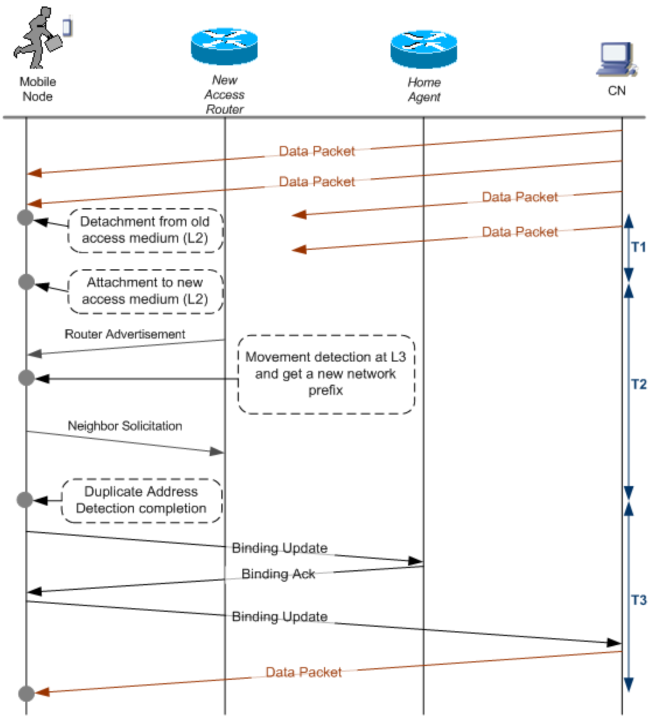

FIG. 5 HANDOVER LATENCY COMPONENTS

T1 is the layer-2 (L2) handover latency i.e., the time used by the specific link layer to attach to the new access medium. If the scenario is a WLAN, this is the handover procedure to switch to a new access point.

T2 is the time taken by the mobile node to detect the presence of a new access router at the new IP subnet; complete, if needed, Duplicate Address Detection (DAD); and configure a new Care-of Address (CoA). This is also known as the rendezvous time delay and it is affected by the amount of overlap or distance between the two neighbouring coverage areas, the speed of the mobile node and the rate of unsolicited Router Advertisement beacons.

The third component (T3) is the time it takes to update the binding in both the home agent and CN. This update is carried out by means of Binding Update (BU) and Binding Acknowledgement (BA) messages. This time lasts until the resumption of communications indicated by a new data packet arriving at the mobile node from the new access router. This is also known as the registration delay.

Since different MIPv6 handover analysis research has been made (*A. Cabellos-Aparicio, et al., 2005*), in this work we supplement and contrast the aforementioned research with a measurement analysis and an evaluation of the stages identified in the handover process. Next, we present the data obtained in the simulations carried out with OMNeT++, a discrete event simulation environment.

The first phase (T1) is the layer 2 handover and represents 12% of the total handover latency. The second stage (T2) is the time spent by IPv6 mechanisms to realize that it is attached to a new subnet and to obtain a new CoA. This is the 87% of the total time. Finally, the own MIPv6 operation is carried out in the third phase (T3) and composed of the time that the MN needs to announce its new location.

Therefore, T3 is the time taken for the MN to register the new CoA in the home agent, to perform Return Routability (RR) test, and then to register it with the CN. This time represents only the 1% of the whole handover process. Accordingly, the value of the handover delay is given by:

$$Thandover = TL2handover + TL3handover \qquad (1)$$

where TL2handover is the time necessary to complete a link layer handover and TL3handover is the time needed to perform a layer-3 handover. In this work, our attention is focused on L3 handover delay since IP is the enabling technology for mobility support. In detail, this time results:

$$TL3handover = TIPv6 + TMIPv6 \qquad (2)$$

where TIPv6 is the time used by IPv6 mechanisms, such as neighbour discovery process (or movement

detection) and CoA configuration. This time is as follows:

$$TIPv6 = TMD + TCoA \quad (3)$$

Finally, TMIPv6 is the time used by MIPv6 tasks and corresponds with T3 in Fig. 5. This time is given by:

$$TMIPv6 = THARegistration + TCNRegistration \quad (4)$$

According to the aforementioned measurement, the time consumption percentage by each phase is shown in Table 1.

As Table 1 shows, T1 and T3 involve only the 13% of the whole handover delay. However, T2 is the main responsible of the high latency in handover process, so most of the time (87%) is devoted to IPv6 tasks.

FDML3: A Fast Detection Movement Proposal

In previous section, MIPv6 handover process has been evaluated, with its different phases analyzed, detecting that the so-called T2 or TIPv6 is the costliest stage. Movement detection is a crucial task in the overall process, because at the time a mobile node establishes a new link-layer connection, and a subnet change also might have occurred.

TABLE 1 PHASES IN MIPV6 HANDOVER

Handover phases	Time
T1=TL2Handover	12%
T2=TIPv6	87%
T3=TMIPv6	1%

This allows knowing whether its default router is on this link yet. This mechanism is carried out in T2 and based on IPv6 Neighbour Discovery (ND) (*T. Narten, et al., 1998*). Movement detection in MIPv6 is too costly in spite of modifications performed by MIPv6 in Neighbour Discovery process. Initially, ND was designed to use it in fixed networks, so its use in mobile environments requires some modifications:

- An additional option (H, Home Agent Flag) in Router Advertisement message is defined to indicate that the router sending the Advertisement message serves as a home agent on this link.
- MIPv6 allows sending Router Advertisements more frequently than the minimum of 3 seconds established in the Neighbour Discovery protocol specification, because this time is not suitable to provide timely movement detection for mobile node. This way, routers supporting mobility can be configured with a smaller value. MinRtrAdvInterval and MaxRtrAdvInterval limit this interval and can be set up till 0,03 and 0,07 seconds respectively.

Some studies have provided a mathematical analysis of movement detection mechanism in MIPv6 (*Young-Hee Han, et al., 2006*), (*J. S. Lee, et al., 2004*). Other proposals associated with handover latency try to overcome this delay with prediction techniques from layer 2 information. In (*A. Safa-Sadiq, et al., 2012*), a smart handover prediction system has been proposed based on curve fitting model to perform the handover algorithm.

In this work, a layer 3 fast detection movement mechanism called FDML3 has been put forward (Fast Detection Movement Layer 3). This algorithm starts from the research developed in (*N. Blefari-Melazzi, et al., 2005*). The system flowchart shown in Fig. 6 is explained next.

1. A mobile node detects that an unsolicited Router Advertisement (RA) has been lost. This situation is known by the network layer because of the absence of a new unsolicited RA in an interval equal to the advertisement interval option configured.
2. The mobile node sends a Router Solicitation (RS) message to the access router to check the bi-directional reachability. This is used to know if the RA has been lost by a network failure or because of the mobile node is out of the current router coverage area.
3. If a RS is not received in an interval between 0 and MAX_RTR_SOLICITATION_DELAY (1 second), it is possible to suppose that the lost has occured due to a mobile node movement.
4. Mobile node tries to connect a new access router to complete the handover. This is done by listening RA messages sent by routers periodically. The network prefix obtained in a RA message is used to configure the new CoA. This new IP address is registered in the HA and CN through Binding Update messages. This last tasks does not correspond to movement detection, although part of MIPv6 handover process.

Comparing this movement detection algorithm with the proposed in (*C. Perkins, et al., 2011*), we can conclude that if unsolicited RA messages are sent with an average interval greater than 1 second, FDML3 offers better results. In the same way, a value of MaxRtrAdvMissed greater than 1 also provides better results. Otherwise, if RA frequency is less than 1, the

proposed algorithm does not improve the movement detection time and in consequence the handover delay.

The interval between unsolicited RAs is set by the IPv6 neighbour discovery mechanism. This protocol establishes the interval limits in 4 and 3 seconds. However, in mobility environments, these values can be reduced to get better results in movement detection as explained before.

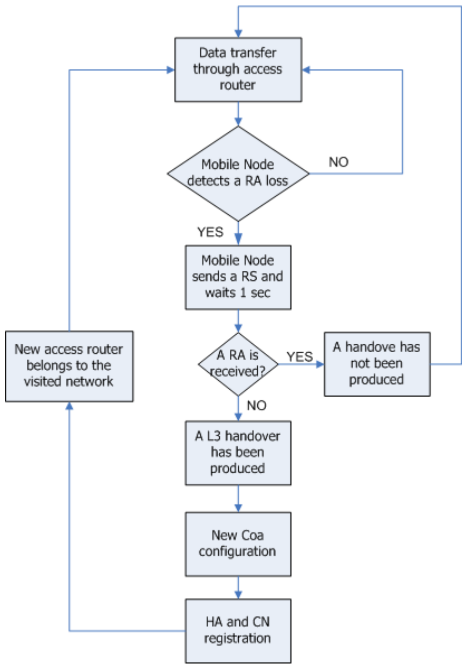

FIG. 6 FDML3 FLOW CHART

The drawback of increasing the unsolicited RA rate is the amount of signalling introduced in the network. The best option in a network with a high amount of mobile nodes is to establish a short interval between unsolicited RAs. This should be an intermediate value to achieve fast movement detection without flooding the network with signalling messages.

Otherwise, in a network where there are few mobile nodes, the most suitable configuration is to set up a long interval between unsolicited RAs to avoid an excessive signalling traffic. MIPv6 is a protocol designed to manage global mobility (or macromobility). Protocols that manage local mobility (or micromobility) are more suitable to handle lots of movements, due to the amount of handovers in a local domain. Next section shows the results obtained by handover and FDML3 simulations in a MIPv6 network.

Results

Both the analysis of handover parameters, explained in the third section of this article, and the evaluation of the proposed FDLM3 algorithm, have been performed with OMNeT++ simulator. Several simulations have been carried out to obtain these results, but in this article, we do reference to the simulation scene shown in Fig. 7. This MIPv6 scene is composed of nine routers, one of which acts as home agent (HA); nine wireless access points; a mobile node (client1); and a correspondent node (CN).

The mobile node moves across the nine access points, so eight layer 3 handovers will be managed. The movement across the scene follows a circular path.

First three tests are dedicated to checking the MIPv6 handover behaviour depending on the different parameters values.

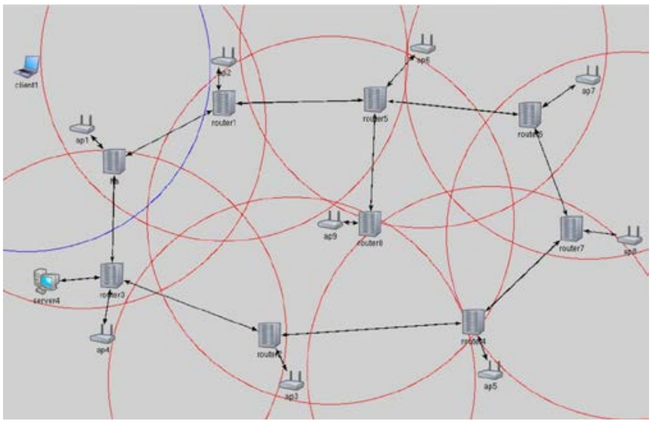

FIG. 7 SIMULATION SCENE

The last test presents the comparison between the MIPv6 movement detection algorithm [3] and FDML3. In other words, the four tests that appear in this section are:

1. MIPv6 handover operation with and without link-level information.
2. Influence of unsolicited RA interval, given by MaxRtrAdvInterval and MinRtrAdvInterval values.
3. Analysis of handover process depending on MaxRtrAdvMissed value. This parameter determines the number of missing RAs needed to validate that a movement has occurred.
4. Comparison of MIPv6 handover depending on movement detection algorithm used (FMDL3 evaluation).

For each test, a table with the following information is presented:

- Overall MIPv6 handover time.
- Round Trip Time (RTT).
- Data lost percentage in transmission.

Link-Layer Triggers

Although our proposal considers network-layer, the

appropriate place to implement mobility capacities, is important to compare the behaviour when link-layer information is used. Fig. 8 shows a chart where link-layer and network-layer handover times are compared.

As it can be seen in Fig. 8 and in Table 2, the difference between both time is very large. Nowadays, it is difficult to think in a mobility environment where link-layer information is not used to complete a handover. In this regard, L2 handover time is 75% less than the L3 one. To achieve a complete mobility among heterogeneous networks, it is necessary to get better results in link-layer independent handover.

Regarding to packet loss, it naturally is lower according to the time of the whole process. Finally, RTT average offers similar data because the routing path is the same in both simulations.

TABLE 2 SIMULATION DATA. L2 TRIGGERS

	With L2 triggers	Without L2 triggers
Handover time (sec)	0,58	2,3
Packet loss (%)	1,71	2,77
RTT average (ms)	151,36	151,36

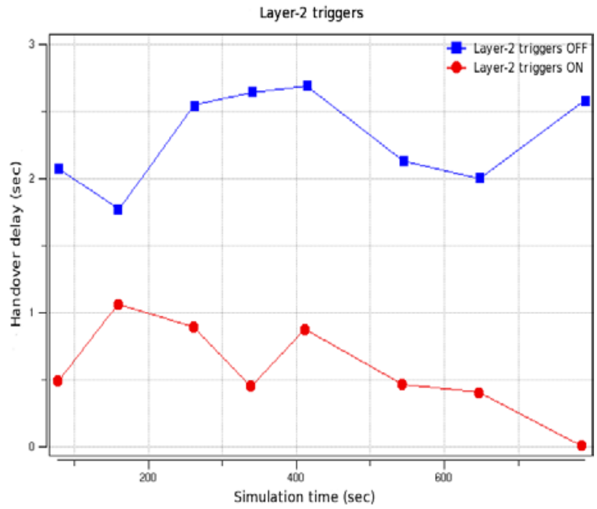

FIG. 8 HANDOVER DELAY WITH AND WITHOUT L2 TRIGGERS

Interval between Unsolicited RAs

Routers send unsolicited RAs to advertise its presence to other nodes in an interval defined by two parameters: MaxRtrAdvInterval and MinRtrAdvInterval. As explained in section 4, MIPv6 modifies the default values of these parameters recommended in (*T. Narten, et al., 1998*) to allow fast movement detection in network layer.

Fig. 9 shows L3 handover delay in four simulations, where these two parameters change its values. Obtained data are also shown in Table 3. Handover delay is influenced by the value of these two parameters. If routers send unsolicited Router Advertisements faster, the time needed to detect the movement will be shorter. This does not mean a low configuration of these variables, because a high amount of signalling traffic supposes an extra overload in the network. As it was shown in previous test, packet loss is lower according to the time of the overall process.

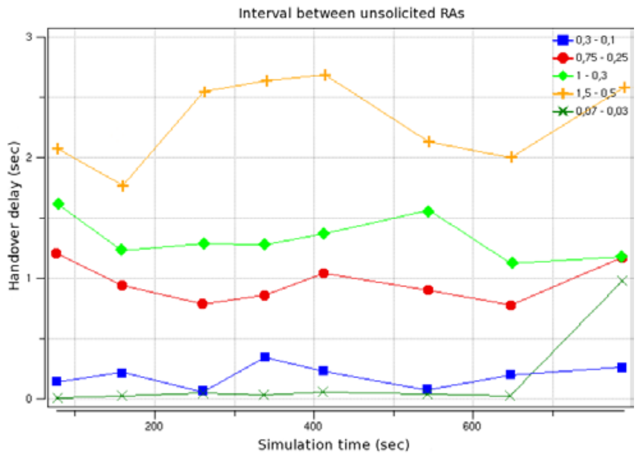

FIG. 9 HANDOVER DELAY. UNSOLICITED RA INTERVAL

TABLE 3 SIMULATION DATA. UNSOLICITED RA INTERVAL

	0.5-1.5	0,3-0,1	0,25-0,75	0,1-0,3	0,03-0,07
Handover time (sec)	2,30	1,32	0,96	0,18	0,15
Packet loss (%)	2,76	2,20	1,87	1,47	1,21
RTT average (ms)	151,13	151,41	151,50	151,61	151,64

Number of Consecutive RA lost

This proof analyzes the amount of consecutive RA that can be lost until network layer is aware of the movement. Several simulations have been carried out to check the influence of a parameter called MaxRtrAdvMissed. Chart shown in Fig. 10 compares handover delay with two values of this parameter, the most common values: 1 and 2. Obtained data in these simulations are presented in Table 4.

Naturally, handover delay increases when the number of consecutive RA messages that have to be lost is higher. So this parameter is configured depending on network behaviour. This is, if network is not reliable because of interferences or bad coverage, can be a good option to set up this value greater than one. In other cases, the lowest value will offer the best performance.

Fast Movement Detection Layer-3: FDML3

This proof checks the behaviour of the proposed Fast

Detection Movement Layer-3 algorithm in MIPv6 handover. To do it, simulations have been made using MIPv6 and the proposed algorithm. Fig. 11 shows the chart of the comparison between MIPv6 environment with FDML3 and without it. Table 5 presents the data obtained in this simulation.

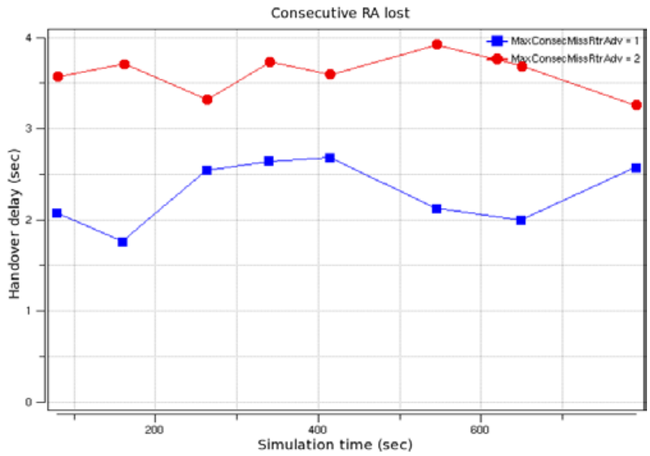

FIG. 10 HANDOVER DELAY. CONSECUTIVE RA LOSSES

TABLE 4 SIMULATION DATA. CONSECUTIVE RA LOST

	RA lost = 1	RA lost = 2
Handover time (sec)	2,30	3,60
Packet loss (%)	2,77	3,74
RTT average (ms)	151,13	151,11

As it can be seen, when FDML3 is used, handover delay is reduced in an average of 25.6%. However, this improvement can not be so high in different situations. Depending on the value of the different parameters presented, the improvement can be less than this percentage.

In this way, if unsolicited RA interval established is low, the handover delay is not improved. However, this configuration increases the amount of signalling traffic in the network.

This overhead should be avoided, therefore this configuration will not be chosen and Fast Detection Movement Layer-3 algorithm will improve the delay of the overall handover process in MIPv6 protocol, allowing mobile nodes to move faster among heterogeneous networks.

Conclusions and Future Work

One of the main limitations in the use of MIPv6 in next generation mobile networks is the interruption time caused by the handover delay among networks that belongs to different administrative domains or among heteregenous networks that use different wireless access technology.

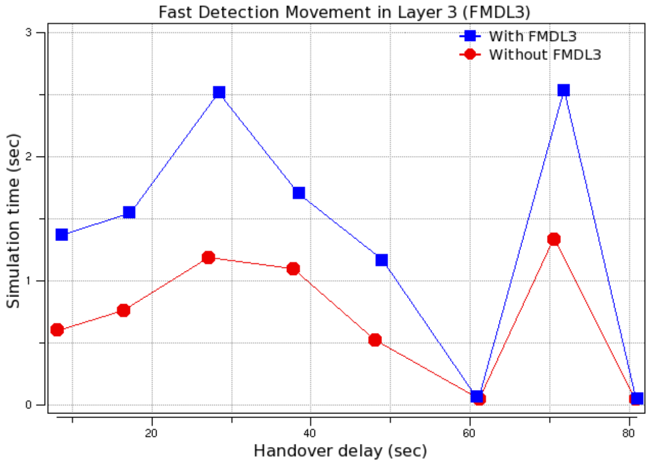

FIG. 11 HANDOVER DELAY IMPROVEMENT WITH FDML3 ALGORITHM

TABLE 5 SIMULATION DATA. FDML3 ALGORITHM

	With FDML3	Without FDML3
Handover time (sec)	1,63	2,19
Packet loss (%)	3,62	4,04
RTT average (ms)	151,10	151,83

In this work, a MIPv6 handover evaluation is presented, checking each phase of the process. This analysis has been carried out using OMNeT++ simulator. Obtained data show that there is a phase very costly in time terms (87% of the process). In this stage, movement detection is performed, so it is a critical part of the process. Due to this limitation, a new fast movement detection algorithm has been developed: FDML3, with which, the overall delay is improved up to 25%.

Although this research work reduces the handover delay, there are other three important sources of delay in MIPv6 handover: Router advertisement, duplicated address detection (DAD) and Binding Update RTT. The study and improvement of these three topics will be presented in future work.

REFERENCES

Abduljalil, F. M., Bodhe, S. K., 2007. A Survey of Integrating IP Mobility Protocols and Mobile Ad Hoc Networks. In IEEE Communications Surveys & Tutorials, vol. 9, no. 1, pp. 14-30.

Blefari-Melazzi, N., Femminella, M., Pugini, F., 2005. A Layer 3 Movement Detection Algorithm Driving Handovers in Mobile IPv6. In Wireless Netwoks. Vol. 11 (Springer), pp 223-233.

Cabellos-Aparicio, A., Serral-Gracià, R., Jakab, L., Domingo-Pascual, J., 2005. Measurement based analysis of the

handover in a WLAN scenario. In Passive and Active Measurement Workshop 2005, March 31-April 5, pp 203-214. ISBN 3-540-25520-6, Boston (USA).

Han, Young-Hee, Hwang, Seung-Hee, 2006. Movement Detection Analysis in Mobile IPv6. In IEEE Communications Letters, vol. 10, no. 1, pp. 59-61.

Koodli, R. S., Perkins, C., 2007. Mobile Internetworking with IPv6: Concepts, Principles and Practices. Wiley-Interscience.

Le, D., Fu, X., Hogrefe, D., 2006. A review of mobility support paradigms for the Internet. In IEEE Communications Surveys, vol. 8, no. 1, pp. 38-51.

Lee, J. S., Koh, S. J., Kim, S. H., 2004. Analysis of Handoff Delay for Mobile IPv6. In Vehicular Technology Conference. VTC 2004-Fall, September 26-29, vol. 4, pp 2967-2969. ISBN 0-7803-8521-7, Los Angeles (USA).

Mangues-Bafalluy, J., Cabellos-Aparicio, A.., Serral-Gracià, R., Domingo-Pascual, J., Gómez-Skarmeta, A.., De Miguel, T. P., Bagnulo, M., García-Martínez, A, 2004. IP Mobility: Macromobility, Micromobility, Quality of Service and Security. In UPGRADE: The European Journal for the Informatics Professional, vol. V, no. 1.

Masaya, C., Pierre, S., 2007. An Architecture for Seamless Mobility Support in IP-based Next-Generation Wireless Networks. In IEEE Transactions on vehicular technology, vol. 57, no. 2.

Narten, T., Nordmark, E., Simpson, W., 1998. Neighbor Discovery for IP version 6 (IPv6). IETF RFC 2461.

Perkins, C., Johnson D., and Arkko, J., Mobility Support in IPv6. IETF RFC 6275. July 2011.

Safa-Sadiq, A., Abu-Bakar, K., Zrar-Ghafoor, K., Lloret, J., Ali-Mirjalili, S., 2012, A smart handover prediction system based on curve fitting model for Fast Mobile IPv6 in wireless networks. In International Journal of Communication Systems (Wiley),.

Javier Carmona-Murillo is a PhD student in the Computing Systems and Telematics Engineering Area (UEx), where he received his MEng in Computer Science Engineering (2005). He has published many articles in journals and conferences related to computing and networking. His main research topics are broadband networks, QoS provision in mobile networks and IP mobility.

José-Luis González-Sánchez, received his Engineering degree in Computer Science and his Ph.D degree in Computer Science (2001) at the Polytechnic University of Catalua, Barcelona, Spain. He has published many articles and books and directed research projects related to computing and networking. Currently, he is the general manager of the Fundation COMPUTAEX and the Center CénitS.

David Cortés-Polo, received his BS and MS degree in Computer Science at University of Extremadura, 2006. Now, he is a Ph.D. candidate at Telematics Engineering Area (UEx). His areas of interest are IPv6 Mobile Networks, MPLS-TE and QoS support. Currently, he is the Network administrator of the Fundation COMPUTAEX and the Center CénitS.

Francisco-Javier Rodríguez-Pérez received his MEng in Computer Science Engineering at the UEx in 2000, where he is currently a Collaborator Professor of the Computing Systems and Telematics Engineering Department, and a Ph.D candidate of the GITACA research group. His research is mainly focussed on QoS and traffic engineering, packet classification and signaling development over IP/MPLS systems.